REVIEW ARTICLE

Dawn after Black out: A Hope of Light –A Review

Mallikarjun.G.Hudedmani[1], Vishwanath.M.Soppimath[2], Santosh .V.Hubballi[3], Darshana Joshi[4]

Department of Electrical and Electronics Engineering, KLE Institute of Technology, Opposite to Airport,
Gokul , Hubballi , Karnataka, India

ABSTRACT: The modern lifestyles and energy usage patterns have rapidly raised the demand for electrical energy and are completely dependent on it. This necessitates mandatory requirements for the operator to maintain high reliability and stability of the power system. However power system is non linear in nature and its operation keeps changing continuously. When the system is imbalanced it causes a total blackout. A blackout is a total crash of power grid due to an imbalance in power generation and consumption. The probable causes for these blackouts to be caused could be due to serious faults, failure of synchronisation between the generators, natural disasters such as lightning, snow, rain, short circuit, switch gear failure and so on. There is a need to improve the security and stability of the power system which should be very high. Learning from the blackout makes it significant to be more cautious and careful in the operation and maintenance of the power system components. In order to avoid catastrophic outages appropriate control actions must be taken which includes software algorithms, use of computer technology, integration of relay models and control device models including emergency control systems in the dynamic simulation software tools. Thus many new concepts and technologies are emerging to make a power system more reliable and efficient so as to overcome the difficulty caused by the blackouts and to avoid it as much as possible keeping the stability power system.

KEYWORDS: Blackout, Disaster, Electric Failure, Grid collapse, Stability.

https://doi.org/10.29294/IJASE.6.1.2019.1264-1271 **© 2019 Mahendrapublications.com, All rights reserved**

1. INTRODUCTION

In the olden days, when the power system was very small, the vertically integrated monopoly power system management structure was more secure. But the modern power system is pushed close to critical operating limits in the market environment. All the equipments used today are completely dependent on the electrical energy. Today's mostly uninterrupted power system has made the world to completely depend on the electricity industry without any backup generations. The human lifestyle now totally relies on the power system. Thus, one cannot imagine life without electrical energy even for few minutes or hours. Power system keeps running in the safer zone till there is proper balance between the generation and consumption. Whenever the power system becomes imbalanced, there is a chance of a blackout [1-2]. A blackout is caused when there is an imbalance in power generation and power consumption. The term power outage is also known as blackout. Last decade witnessed such major blackouts namely in USA, Australia, Ireland, Brazil, India and few other countries. The blackout that took place in India in year 2012 was the longest and largest. Almost 22 states and 620 million peoples got affected. When a blackout occurs the entire affected part is deprived from the electrical energy networks. Blackouts are resulted due to faults in lines, insulation failure, rupture of conductors, faults on the generation side and so on. Most of the time blackout is resulted because of the combination of extreme weather events, human error, poor preparation and aging of equipment etc. Sometimes minor issues result major blackout. Usually all the industries, schools, trains, airports and all the other systems depend on electricity are affected. This could threaten power system security, reliability and also lead to a major economic loss to the country. For the specific sites the power failure is critical where the environment and public safety is at risk. Learning from previous blackouts help in developing better control and necessary changes required in maintaining and improving the stability and reliability of the power system. Some of the preventive measures would be trimming of trees regularly, reduction in the energy consumption which involves turning the off lights that aren't in use or necessary. Daylight savings will keep building bright until twilight. While using an air conditioner, keep the doors shut to any rooms that aren't being used. One adoptable measure would be building a smarter power grid that automatically responds to problems could reduce the rising blackouts. The modern technology is growing so fast that with the help of intelligent algorithms and computers, automated power system can be produced

Corresponding Author:* **mallikarjunh@yahoo.com

Received: 07.06.2019 **Accepted:** 18.07.2019 **Published on**: 28.08.2019

which acts more precisely than human and increases the stability and reliability of the system. The new trend of using high voltage direct current (HVDC) and flexible ac transmission system (FACTS) devices also ensures an improved power system with least possibility of blackouts and more power supply to its consumers [3-4].

2 LITERATURE SURVEY

In the history, several major blackouts were reported separately in many research articles. The present work highlights the historical background and reviews on blackout. The identified root causes, lessons learnt from the blackouts and solutions are addressed while briefly discussing the blackout events presented [5]. Large-scale blackouts in North America, Europe and other countries, such as the 1996 blackout in the U.S, the 2003 blackout in North America the 2003 blackout in Italy and the 2006 blackout in Europe are the reminders of the importance of the reliability of the electric energy infrastructure and the economic impacts. Analysis of these blackouts reveals that these outages were caused by a cascading sequence of events including simple line tripping, overloading of transmission lines, malfunctions of protection systems, power system oscillations and voltage instability, system splitting and collapse. Many publications present and discuss common characteristics of blackouts by analyzing the cascaded events of major blackouts. More specifically, fundamental patterns of cascaded events following a contingency, including the causes, evolution and dynamics of cascaded events are identified [6]. The modern power system is very complex and operating with critical operating limits and challenges. High capacity and long transmission networks are widely used to meet the power supply demand of modern society of mixed mode choices users. Wind and solar power is clean and renewable among those sources. These energy systems are significantly adopted but they are inherently volatile, intermittent and random. Therefore, an improper handling of certain partial failures can easily lead to accidents and severe chain reactions and thus may cause large-scale or extensive blackout eventually. Power system restoration has captured greater attention and made great progress recently. Research progress of the power system restoration from 2006 to 2016 is reviewed and discussed black-start, network reconfiguration and load restoration. Some emerging methods and key techniques are identified and presented in the context of the integration of renewable energy and development of the smart grid. Due to the extreme complexity of the system it is little difficult and long way to go to achieve automatic self-healing. However, rapidly developing artificial intelligence and machine learning technology eventually enable the dynamic decision-making systems for the need. The use of supervisory control and data acquisition systems (SCADA) and wide area measurement systems (WAMS) in the near future is very essential and secure the system [7].

A case study of grid disturbances which occurred on 30th and 31st of July 2012 left millions of Indians in the dark many hours before the restoration. It was understood that in the blackout that occurred on 31st of July, hydro power was slowed down which led to inadequate power generation while people overdrew more power for cooling off since the temperature was extremely high. One of article presents investigations of the main reasons for the occurrence of the blackout. There are several simulation tools available for the power system simulation and analysis. One of such is used to develop a simplified simulation model with DIgSILENT Power Factory to reproduce and analyze the grid behaviour when the blackout occurred. The conclusion after the sensitivity analysis and policy the strategies are recommended to enhance the grid security and robustness. Two extremely serious blackouts occurred in the Indian power grid at the end of July, 2012. Three of the Indian Grids were hit by power failure, leaving a huge disturbance in the country. The power outage affected 620 million people in India. One of the articles in the literature referred proposes a method to forecast and study the load recovery behaviour during restoration of power systems after total or partial blackouts. A heuristic top-down approach was adopted to develop the forecasting method, using an expert system based on linguistic variables and fuzzy logic rules as its central core. The approach addresses the main aspects of load behaviour during re-energization and is capable of representing physical phenomena. The proposed methodology was found tested with data from real electrical power substations [8-9].

A novel application of Artificial Neural Networks (ANN) to prevent blackout in a micro grid after N-1-1 contingency condition. In fact, micro grids are vulnerable to disturbances and abnormal conditions due to their inherent small inertia. Therefore, stability of micro grids after a disturbance turns into a challenge in power systems. The use of artificial intelligence to prevent cascading failure practically at early stages and to make micro grids more reliable and robust by intelligent and adaptive re-dispatch of power. Experimental results verify the robustness, accuracy and effectiveness of the ANN method for preventing cascading failure in addition to providing voltage and frequency stability after initiation of a disturbance. With the analysis of blackouts and important disturbances in Europe since 2003 and describes the sequence of events and challenges restoring the grid. The concrete measures to enhance the reliability of the grid, experiences in utilities and with system integrators to strengthen the system were discussed [10-11]. Phase after the restoration of a power system just under gone a total black out poses some serious issues and challenge for power system operators. The main reason is the necessity of black start units. Mainly due to economic reasons and other riding factors sometimes it is not feasible to provide black star capability for every power station. The location and capacity of black start units play an important role in deciding the restoration strategy after a black out. Bulk grid restoration takes long time and the parallel building up and synchronization of electrical islands is the generally accepted practice for bulk grid restoration. In case of a total blackout, finding an amicable solution to important restoration tasks like the choice of number of independent islands, configuration and loading of the islands, keeping reserve capacities and selection of restoration path requires assessment of black start capability of plants and location of the black start unit using a restoration algorithm that can be used on the event of a total blackout and application of the same is proposed for the case study of North Kerala grid [12].

3 BLACKOUTS FROM HISTORY AND LEARNING FROM THE PAST

Robust trends in the blackout data can often be valuable inputs to the investment and policy decision-making process. The causes and effects of blackouts in the past can indicate that it is important to design energy delivery infrastructure to be robust and secure. Few blackouts that took place in different geographical areas in the past and their effects are listed for comparative study in the recent years is illustrated below. Table 1 presents the data related to different black out situations observed globally and the impact [1,4,5]

Table 1 History of blackout

Article	People affected (millions)	Location	Date
2012 India Blackouts	620	India	30th & 31st July 2012
2014 Bangladesh blackout	150	Bangladesh	1st November 2014
2015 Pakistan blackout	140	Pakistan	26th January 2015
2009 Brazil and Paraguay blackout	87	Brazil, Paraguay	10th &11th Nov 2009
2015 Turkey blackout	70	Turkey	31st March 2015
2016 Kenya Blackout	44	Kenya	7th June 2016

(Reference: Compiled from the listed references)

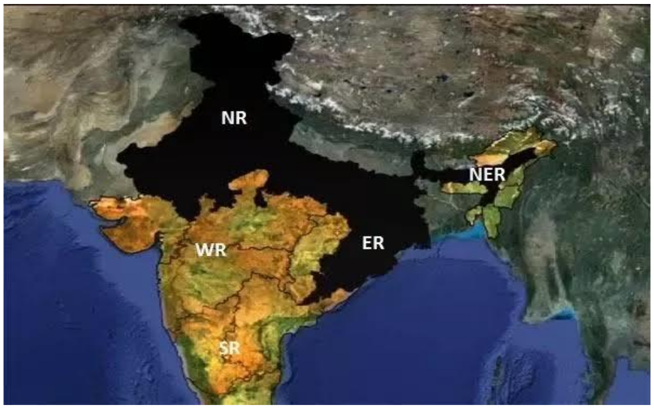

Fig 1 Image of India during blackout 2012

(Reference: CERC investigation report)

3.1 Indian Blackout 2012

India is the world's third largest producer and consumer of electricity from mixed mode of generation after the United States and China. However, generally the electrical infrastructure is considered unreliable due to dynamics of system. The last blackout in year 2001 in the northern electrical grid is witnessed the similar. In 2012, an estimated 27% of energy generated was lost in transmission or stolen, while peak supply fell short of demand by an average of 9%. During that period, the nation suffers from frequent power outages that last as long as 10 hours and about 25% of the population, about 300 million people, had no electricity at all. The efforts put to reduce transmission and distribution losses and to increase production went waste [8]

- **July 2012:** Two severe power blackouts affected most of northern and eastern India on 30th and 31st July 2012. The 30th July 2012 blackout affected over 400 million people and was the largest power outage in history of electrical power system by the number of people affected

Mallikarjun et al.,

overriding the January 2001 blackout in Northern India (about 230 million affected). The blackout on 31st July is the largest power outage in history. The outage has affected half of India's population and about 620 million people that is 9% of the world population. The total of 22 states in Northern, Eastern, and Northeast India were disturbed.

- **Causes:** The blackout was caused by an overloading event that happened on the 400 KV Gwalior-Bina transmission double lines (one of the double lines was under maintenance). Therefore, the overloading caused a cascade of tripping through the network, leading to approximately 32 GW of generation shortage. Due the higher demand with the lack of generation and the inadequate response to the issue, the system failed again on 31st of July.

3.2 Bangladesh Blackout 2014

The Bangladesh utility electricity sector has one national grid with an installed capacity of 16,525 MW as of 13th September 2018, but the total installed generation of 20,000 MW (combining solar power). Bangladesh's energy sector is booming. Recently Bangladesh started construction of the 2.4-gigawatt (GW) Rooppur Nuclear Power plant expected to get into operation by 2023. As per the information the Bangladesh Power Development Board in July 2018, the country has low per capita energy consumption and about 90% of the population had access to electricity [1,7].

- **November 2014:** About 100 million people in Bangladesh, out of a total 160 million were without electricity for about 10 hours on November 1st. The rest of the population has no access to the national grid. The disturbance basically started at 11.30 am at Bheramara substation located in Kushtia district soon it knocked the 400 KV transmission line that was carrying 445 MW of power from India. As the national grid lost about 445 MW of power, an uncontrolled chain reaction set in. All the power plants of the country were forced to shut down.
- **Causes:** The tripping of the transmission line at Bheramara resulted loss of about 445 MW of power received from India due to the same Bheramara substation was unable to handle any power beyond 400 MW. The effect of the same was to experience fall in frequency to 45Hz and its impact created an electric surge resulting a country wide blackout.

3.3 Brazil and Paraguay blackout 2009

Paraguay is the only country in Latin America with almost 100 percent hydroelectric generation capacity (8,116 MW) in 2005. Paraguay operates two bi-national hydroelectric dams. With 24 plants having 1000MW each mainly by hydroelectric the Brazil accounts 77% of total installed capacity. About 88% of the electricity fed into the national grid is estimated to come from hydroelectric generation, with over 25% coming from a single hydropower plant, the massive 14 GW Itaipu dam facility, located between Brazil and Paraguay on the Paraná River. Natural gas generation is second in importance representing about 10% of total capacity close to the 12% goal for 2010 established in 1993 by the Ministry of Mines and Energy [4],

- **November 2009:** The 2009 Brazil and Paraguay blackout affected an estimated 60 million people in Brazil. Thousands of passengers were stranded as metro trains came to a halt and buses failed to cope with the volume of passengers. There were widespread reports of road accidents as street lighting and traffic lights failed. The power outage began on Tuesday, November 10th, 2009, at approximately 22:15 BST. The blackout began about 22:15 on Tuesday and lasted until about 02:45 on Wednesday in Sao Paulo, although power was restored gradually in some places from before midnight
- **Causes:** Heavy rains and strong winds caused three transformers on a key high-voltage transmission line to short circuit, cutting the line and automatically causing the complete loss of 14 GW power outage and the shutdown of the Itaipu Dam due to the heavy rain fall and other associated consequences resulted first time in its 25 years of history. This power outage affected 18 of the 26 countries and brought chaos to cities including São Paulo, Rio de Janeiro, Belo Horizonte, Campo Grande and Vitoria. Media such as Slashdot and 60 Minutes reported the outage as the work of hackers.

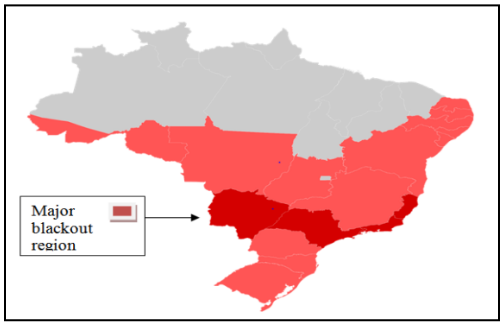

Fig 2 Map showing the regions affected by blackout
(Reference: 2009 Brazil and Paraguay blackout en.wikipedia.org)

All countries across the world prepare themselves to situations like the blackouts. Even though blackouts do not appear regularly, but a backhand protection is must for a power system to overcome this situation. The blackouts in the past aid us to improve the stability of power system, its reliability and consistency of secure operation. Safe operation of the power system is vital. Thus as the quotes states, "Prevention is better than Cure", preventive measures are necessary to avoid blackouts as much as possible.

4 CAUSES OF BLACKOUTS AND GENERAL CONTROL STRATEGY

More often when faults occur in the power system, there are few common methods used to clear the faults and bring system back to normal operating condition. It is important for the operator to pay attention even to small faults or disturbances which cause problems in the system operation. The technologies used in the past decade is, the use of SCADA and HVDC technology for the safe operation of the power system. SCADA is Supervisory Control and Data Acquisition which is software which generally refers to an industrial computer system that monitors and controls a process. In case of the transmission and distribution elements of electrical utilities, SCADA with its associated peripherals get information, monitor substations, transformers and other electrical infrastructure.

The computer programs and algorithms used for the automation of the power system are more reliable and secured when compared to the human operation. But still at times there are chances where faults occur due to ignorance of operator, natural calamities, sudden changes in the load, and disturbances during generation and so on. Hence a protected power system also tends to be in the state of damage or danger further causing the total loss of power causing blackout. Blackouts are not regular, but when it is caused there is huge loss to a country's economy, safety of the public and also to the power system. The new technologies involving less of human intervention and more of machines assures more stability of the power delivery to the consumers. Hence it is necessary to maintain power system at proper operating conditions to keep it healthy and avoid disturbances as much as possible. Hence it is significant to provide proper security and stability for the power system to always operate in normal condition along with the use of recent developments and technologies [10-12].

4.1 Common reasons for the blackouts

- Preexisting conditions e.g. generator/line maintenance, heavy loading.
- Tripping lines due to faults and/or protection actions, causing heavy overloads on other lines. Protection and control disoperation or unnecessary actions (incorrect settings/design or hardware failures) that contributed to disturbance propagation.
- Insufficient voltage (reactive power) support.
- Inadequate right-of-way maintenance.
- Inability of operators to prevent further propagation of the disturbance and problems with energy management system/SCADA (EMS/SCADA) systems to provide only important information when required.
- Inadequate planning/operation studies.
- Automated actions were not available/ initiated to prevent further overloading of the lines, arrest voltage decline, and/or initiate automatic and preplanned separation of the power system [8-9].

Fig 3 Blackout A disaster in power system

(Reference: Venezuela: New Widespread Power Outage venezuelanalysis.com)

4.2 Specific reasons which cause blackout

Preconditions and Symptoms of Blackouts: An important aspect in understanding the underlying cause of system-wide outages is that the current power system was not originally designed to transfer large amounts of power. Interconnected operations of systems improve the network security enabling the neighbor systems to share the loads and support on critical situations. In recent years, deregulation has imposed additional requirements of high transfers from generation sources (e.g., independent power producers) to the load areas. At the same time, public pressures and the “Not in My Backyard” sentiment make it difficult to site lines or major local generation sources, especially in the more heavily populated areas causing more costlier systems and resulting difficulty. Although there is a tendency to point at a “single” event triggering cascading outages, major blackouts are typically caused by multiple contingencies with complex interactions. The likelihood of low-probability events escalating into a cascading outage increases when the grid is already under stress due to preexisting conditions.

- **Weather Conditions and Natural Causes:** Wind, high temperatures, thunderstorms, fog, geomagnetic disturbances, fires, etc., are often triggering elements for cascading disturbances, however there are number of controllable preconditions and symptoms of blackouts, such as grid congestion, insufficient right-of-way maintenance, tight operating margins etc.
- **Effect of Reactive Power:** Another important factor during blackouts in recent years was inadequate reactive support close to the loads. It is very important to assure that sufficient reactive power is available, so that normal voltage levels can be sustained. Other factors include aging equipment that is prone to failure and inadequate maintenance (such as right-of-way maintenance or tree trimming), as well as insufficiently coordinated equipment maintenance and generation scheduling during stressed conditions.
- **Short Circuits:** A short circuit is most commonly used term to describe the cause of power failure which is the flow of current in the unintended path. During such situations an excessive electric current which can lead to circuit damage, fire and explosion. The short circuits are one of the primary causes of electrical fires due to the massive flow of current through the low reactance path taken.

  A combination of these factors makes power systems more susceptible to disturbances. During the cascading events that cause disturbances to propagate and turn into blackouts. When a fault occurs or if the system is stressed and equipment removed without sufficient adjustment, the chain of events may start. At that stage, the power system is faced with overloaded equipment and multiple disturbances evolving in different time scales. The reliability of protective relaying where hidden failures in relays occur is introduced. As it is not really possible to eliminate the black outs completely but it can be shown that, by taking some reasonably cost-effective measures, occurrence of the blackouts could be minimized.

4.3 Preventive Measures that can postpone Blackout

- **Intelligent Mitigation of Blackout in Real-Time Microgrids:** Application of Artificial Neural Networks (ANN) being deployed to prevent blackout in a microgrid after certain critical contingency condition. In fact, microgrids are vulnerable to disturbances and abnormal conditions due to their inherent small inertia. Therefore, stability of microgrids after a disturbance turns into a challenge in power systems. Experimental results verify the robustness, accuracy, and effectiveness of the ANN method for preventing cascading failure in addition to providing voltage and frequency stability after initiation of a disturbance.
- **Prevention of Overloads by System Operation:** The following three procedures can be implemented for mitigating overloads through system operations namely,
  - Network Reconfiguration involving Returning to Service the Out-of-Service Transmission Facilities.
  - Generator Control Involving Generation Output Adjustment and Generation Starting.
  - Voltage Reduction and Curtailment of Non-essential.
- **Grid Restoration Planning:** After a Total blackout for the development of restoration algorithm, the switching operations to be performed are classified into,
- **Preset switches:** Those circuit breakers which can be closed even before the restoration process started come under this category. These circuit breakers include those forming the bus scheme within one substation and not connected to any external transmission line.
- **Dependant switches:** These are circuit breakers which can be closed only on the direction from the restoration coordinator (Load Dispatch Centre).
- **Interlocked Switches:** These are interlocked switches whose operation is not controlled by the restoration coordinator. The operation of such switches are either automatically interlocked with another switch or locally controlled by the substation operator. After selection of a particular load point for restoration, algorithm is used to generate the require switching sequence to restore the load.
- **Self Restoration Mechanism in the New Concept of Frame working:** It is observed that whenever a cascading failure occurs, it leads to a split of phase in the system. When a system splits its one part becomes power deficient and a frequency decrease takes place there whereas for the other part a power surplus takes place in the other part with the frequency increase. The part with power surplus might be slightly elevated in frequency which could retard the merging process

and cause additional power drawl from the inductive machines. So to overcome this frequency sensitive devices are developed to act automatically to disconnect the consumer's lines and as a result of this frequency rises slightly.

- **Prevention of Power Grid Blackouts Using Intentional Islanding Scheme:** Intentional islanding is often conducted to understand behavior and response at the last resort to preserve the electric grid from severe blackouts. The intentional islanding scheme use deliberate segregates of the entire power system into a number of self-sustained islands to understand and obtain the transient stability of the power network. This method utilize spectral clustering algorithm is to obtain an islanding solution, which results in minimal power flow disruption across boundaries of islands. The introduced constraint in the spectral clustering method is based on generator coherency grouping for the study and understanding. The clustering scheme utilizes a more efficient and accurate k-medoids algorithms for the comparison and the results of simulations demonstrate that the proposed method can effectively prevent blackouts by separating the systems into stable islands.
- **Supervisory Control and Data Acquisition (SCADA):** SCADA systems are not only crucial for industrial organizations they are useful in electrical power system also to maintain efficiency, process data for smarter decisions and communicate system issues to eliminate or reduce downtime. SCADA software receives the information from programmable logic controllers (PLCs) or remote terminal units (RTUs) which in turn receive their information from the sensors or input values. It is used to collect, analyze and monitor the data effectively which will save money and time but the implementation cost of SCADA is huge in terms of lakhs. Additionally, many power grids have been changed by installing new components or control schemes therefore, the original protection scheme and grid codes should be revised, including the revision of the design of relay systems, the special protection system, the load shedding mechanism, the grid coordination mechanism, and the measured and control system. Furthermore, renewable energy has been increased remarkably; therefore, the corresponding revision on the protection strategies for incorporating renewable energy is also important. The potential improvement schemes would consist of grid reinforcement, increase of tie-line, re-design of load shedding strategy, planning of suitable locations for new generators, installing more measured and control systems, optimization of reactive power and voltage controls, installing advanced protection relays, and automatic operations and alarm during severe incidents [3-6,10-12]

5. CONCLUSION

In today's modern lifestyles and complete dependence on electrical energy makes it very difficult for human beings to imagine few minutes without electricity. It has become the most necessary commodity of our lives. Thus it is mandate that the power system works continuously. This can be achieved by involving the best of computer algorithms, innovative technologies which can promise safe and reliable operation of the power system. The learning's from the fast blackout scenes helped the power engineers in restructuring and retrofitting the power system in part or whole to bring the advanced control techniques to reduce the probable risks of losing the control and unexpected disasters. Developments in the field of power system are essential and accurate results are required to fulfill the demands of the power consumption. There must be proper balance between generation and consumption which reduces the risk of power failure leading to blackout. Hence, machines and devices are being developed that are more efficient and precise than human being which ensures more security and reliability of the power.

REFERENCES

[1]. Hassan Haes Alhelou, Mohamad Esmail Hamedani-Golshan, Takawira Cuthbert Njenda and Pierluigi Siano, 2019, A Survey on Power System Blackout and Cascading Events: Research Motivations and Challenges, Energies 2019, 12, 682.

[2]. Matthewman, S., & Byrd, H, 2014. Blackouts: A Sociology of Electrical Power Failure. Social Space Scientific Journal, ISSN 2084-1558, January 2014, 7(1), pp. 31-55.

[3]. Hachimenum N. Amadi and Ephraim N. C. Okafor, 2015, Analysis of Methodologies for the Evaluation of Power Outage Costs, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, IJERTV4IS051044, 4 (5), May-2015.

[4]. Gunther Beck, Dusan Povh, Dietmar Retzmann, Erwin Teltsch, 2005, Global Blackouts-Lessons Learned, Power-GEN Europe 2005, Milan, Italy, june 28-30, 2005.

[5]. Arulampalam Atputharajah, Tapan Kumar Saha, 2009, Power System Blackouts - Literature review, 4th International Conference on Industrial and Information Systems, ICIIS 2009, 28th - 31st December 2009, Sri Lanka, 460-463.

[6]. K. Yamashita, Juan Li, P. Zhang and C. Liu, 2009, Analysis and control of major blackout events, 2009 IEEE PES Power Systems

Conference and Exposition, Seattle, WA, 2009, 1-4.

[7]. Yutian LIU, Rui FAN,Vladimir TERZIJA, 2016, Power system restoration: a literature review from 2006 to 2016, Journal of Modern Power Systems and Clean Energy, 2016, 4(3), 332-341.

[8]. Loi Lei Lai, Hao Tian Zhang, S. Mishra, Deepak Ramasubramanian, Chun Sing Lai, Fang Yuan Xu, 2012, Lessons Learned from July 2012 Indian Blackout, 9th IET International Conference on Advances in Power System Control, Operation and Management (APSCOM 2012).

[9]. L.T.M. Mota, A.A. Mota and A. Morelato, 2007, Load behaviour prediction under blackout conditions using a fuzzy expert system, IET Gener. Transm. Distrib, 2007, 1 (3), 379–387.

[10]. S. Zarrabian, R. Belkacemi and A. A. Babalola, 2016,Intelligent mitigation of blackout in real-time microgrids: Neural Network Approach, 2016 IEEE Power and Energy Conference at Illinois (PECI), Urbana, IL, 2016, 1-6.

[11]. T. Schossig and W. Schossig, "Disturbances and blackouts — Lessons learned to master the Energy Turnaround," 12th IET International Conference on Developments in Power System Protection (DPSP 2014), Copenhagen, 2014, 1-6.

[12]. Sreeram R Kurup, Ashok S, Grid Restoration Planning After a Total Blackout, 2015, International Conference on Control, Communication & Computing India (ICCC), 19th – 21st, November 2015, Trivandrum.

All © 2019 are reserved by International Journal of Advanced Science and Engineering. This Journal is licensed under a Creative Commons Attribution-Non Commercial-ShareAlike 3.0 Unported License.